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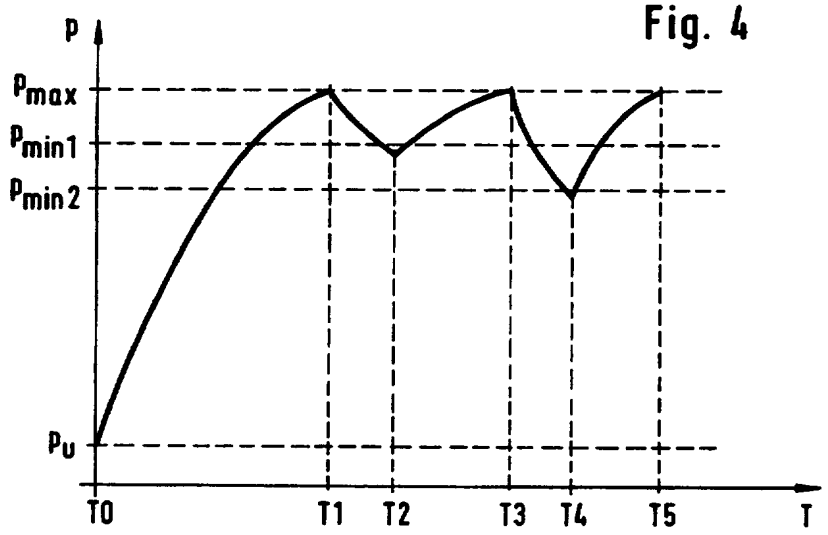
(54) Pressure control system

(57) In a system to control the pressure of fluid in a reservoir supplied by a compressor, the pressure of fluid P in the reservoir is sensed and the compressor speed is controlled accordingly. The compressor is run at its nominal speed when the reservoir pressure $P<P_{min2}$, ie when the system is started up or when a significant withdrawl is made from the reservoir, and is run at a reduced speed when the pressure P is between P_{max} and P_{min1}, where $P_{min2}<P_{min1}$.

The aim is to reduce power consumption by only operating the compressor at its maximum speed when a large pressure increase is required.

Fig. 4



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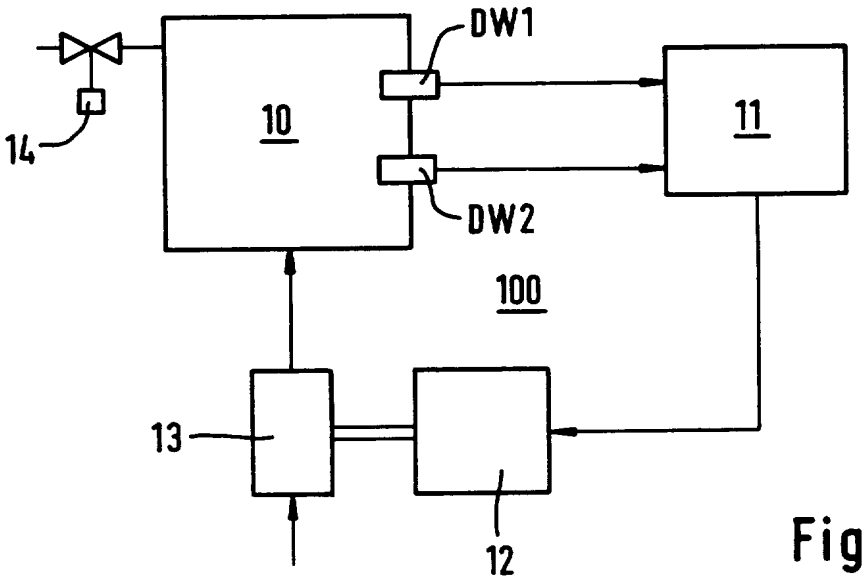

DW1
10
11
14
DW2
100
13
12

Fig. 1

Fig. 2

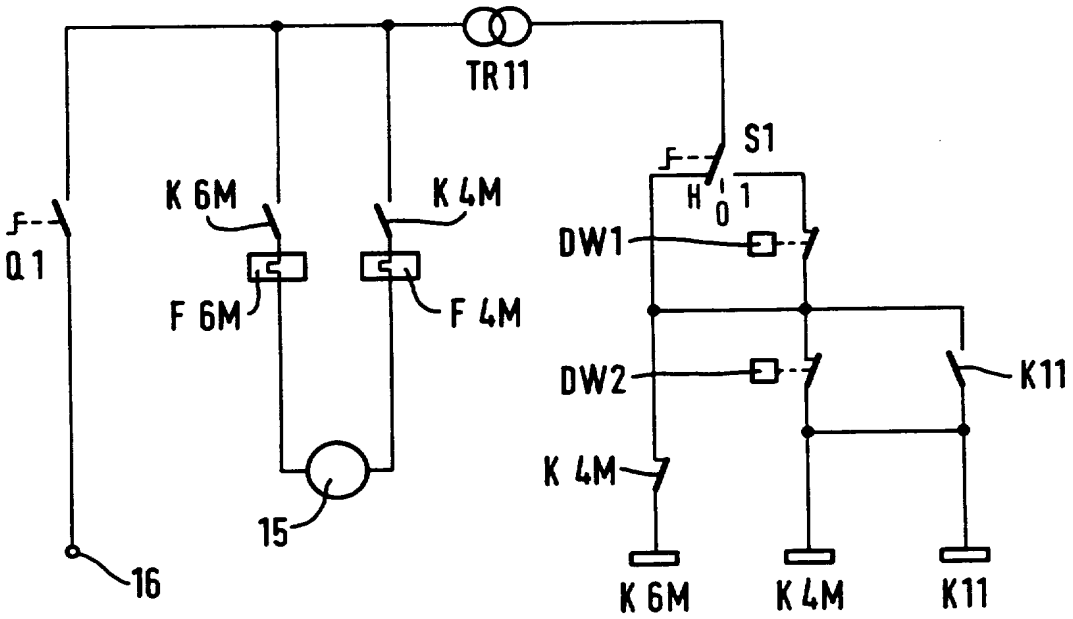

TR11
S1
H
0
1
K 6M
K 4M
Q 1
DW1
F 6M
F 4M
DW2
K11
K 4M
15
16
K 6M
K 4M
K11

Fig. 3

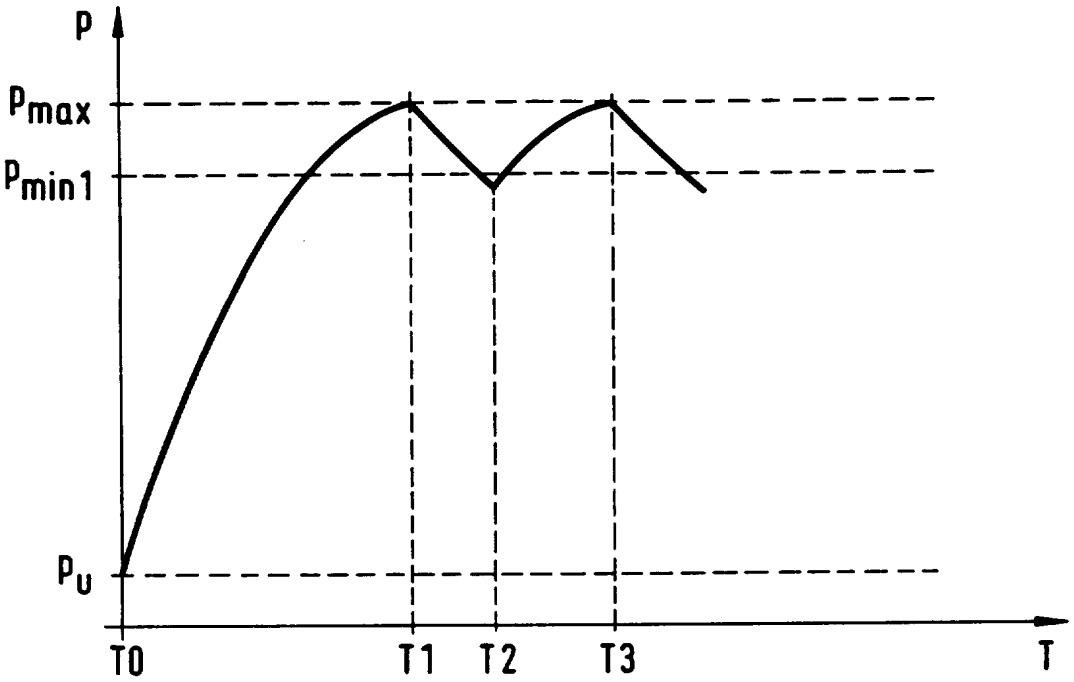
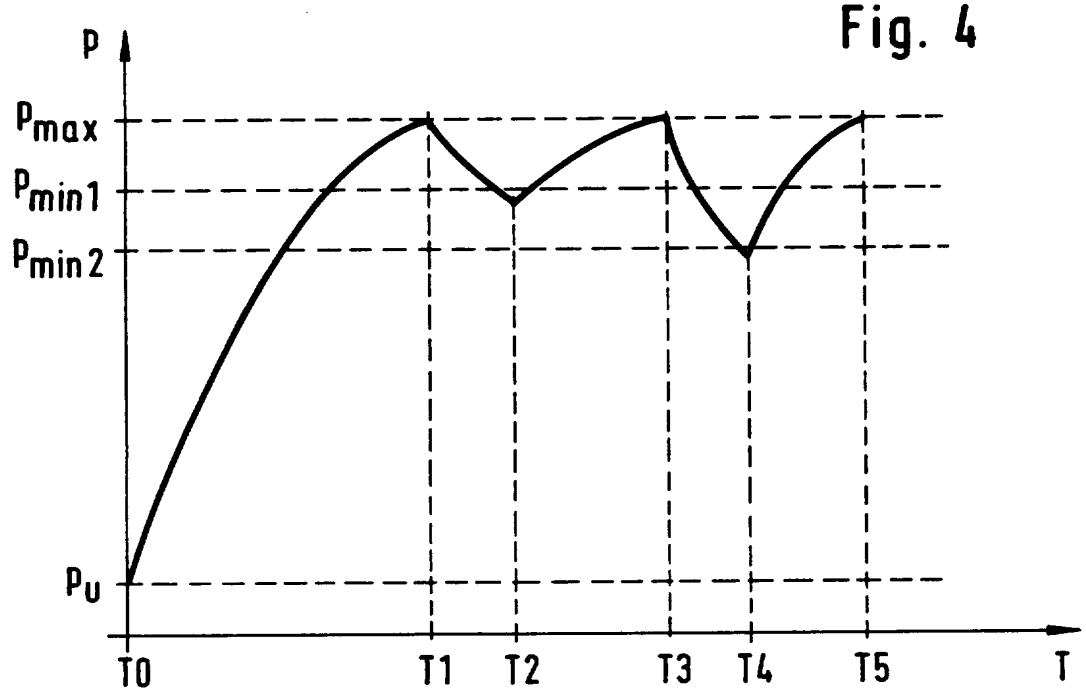

p
pmax
pmin1
pu
T0
T1
T2
T3
T

Fig. 4


p
pmax
pmin1
pmin2
pu
T0
T1
T2
T3
T4
T5
T

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Title: Compressor System

Description

The invention relates to a compressor system which comprises a compressor which with its exit is connected to an air reservoir and is driven by a driving means which in a first mode of operation is operated at a nominal speed, as well as a first pressure control means which controls the pressure of the air reservoir and turns on the driving means by means of a controlling means as soon as the pressure of the air reservoir falls below a first minimum pressure, and turns off the driving means again as soon as a maximum pressure in the air reservoir is exceeded.

Starting air compressors in the navigation field are designed in conformity with their performance according to the requirements of the Classification Societies. Thereat it is made sure that, proceeding from an ambient pressure pu, an air reservoir of a predetermined size can be filled up to a maximum pressure pmax within a certain time T1-TO (operating phase I; see the exemplary diagram of Fig. 3 showing pressure p for time T of a conventional compressor system).

For shipping operation the pressure of the air reservoir is controlled. As soon as a pressure pmin1 is exceeded the compressor starts automatically and fills the reservoir until Pmax is reached within the variable time T3-T2. The compressor turns off automatically again (operating phase II; see also Fig. 3). For filling the reservoirs sequentially according to the operating phase II, the compressors up to now have been operated at the same nominal speed as used in the operating phase I. The wear of the compressor which increases with the second or third power of the number of revolutions, therefore, in the operating phase II is as high as in the operating phase I, though in the first operating phase the power requirements are smaller.

It is the object of the invention now to provide a compressor system, for which the wear of the compressor can be substantially reduced without resulting in any disadvantages for the continuous operation of the system.

This technical problem is resolved for a compressor system of the type mentioned at the beginning in that, besides the first mode of operation in which the driving means is operated at a nominal speed, said driving means in a second mode of operation is operated at at least one further speed being reduced with respect to the nominal speed so that the first pressure control means only turns on if the pressure falls below the second minimum pressure due to a decrease of pressure, and that in the second mode

of operation the second pressure control means controls the driving means at the reduced speed.

The essence of the invention thus consists in operating the compressor at a speed which is lower than the nominal speed which is realized by a corresponding development of the driving means and the controlling means for the sequential filling procedure in the operating phase II. By this, the wear is substantially reduced in those phases in which there is not required the full power of the compressor.

A first preferred embodiment of the inventive compressor system is distinguished in that the pressure of the air reservoir is controlled by a second pressure control means which turns on as soon as the pressure falls below a second minimum pressure as a result of a pressure drop, which second minimum pressure is smaller than the first minimum pressure, and that said second pressure control means switches the driving means from the second mode of operation to the first mode of operation, in which the driving means is operated at a nominal speed. By this, as a result of the correspondingly increased power of the compressor at a nominal speed, it is possible to realize a high-speed refilling in those cases in which the pressure of the air reservoir drops much more rapidly.

According to a further embodiment of the inventive system, the driving means comprises a three-phase asynchronous motor including a frequency control, the

number of revolutions of which is continuously variable.

By this, it is possible to optimize the number of revolutions in response to the pressure of the air reservoir so that there is a minimum wear, with the filling rate being sufficient.

A further, especially preferred embodiment is distinguished in that the driving means comprises a three-phase asynchronous motor including a pole-changing, the number of revolutions of which is continuously variable. By this, the control can be carried through particularly easy and reliable since there is not required any continuous change of the speed and the expenditure of switching involved.

Further embodiments result from the dependent claims.

The invention will be more detailedly explained hereinafter with the aid of examples of embodiments illustrated in the drawings. There are:

FIG. 1 the schematic structure of a compressor system according to a preferred embodiment of the invention;

FIG. 2 the detailed circuit diagram of the controlling means for a system according to Fig. 1;

FIG. 3 the course of the pressure p for the time T for a compressor system featuring a controlled pressure level and a constant nominal speed according

to the state of the art, and

FIG. 4 the exemplary course of the pressure p for the time T for a system according to Fig. 1 resp. 2.

In Fig. 1 the schematic structure of a compressor system according to a preferred embodiment of the invention is shown. The compressor system 100 comprises an air reservoir 10 including two pressure control means DW1 and DW2 which turn on as soon as the pressure falls below two different maximum pressures pmin1 (e.g. 27 bar) and pmin2 (e.g. 18 bar) and turn off as soon as two different maximum pressures (e.g. 30 bar and 20 bar) are exceeded. Thereat the maximum pressure of the first pressure control means DW1 is identical to the maximum pressure pmax of the system. Besides, the compressor system 100 comprises a compressor 13 which takes in air and compresses it into the air reservoir 10, and a driving means 12 for said compressor 13 which, besides a nominal speed Nnenn, provides at least one further reduced speed Nred (Nred = x·Nnenn with $0 < x < 1$) which either can have a constant value or (e.g. if there is a three-phase asynchronous motor including a frequency control) can vary with pressure p (Nred = n f (p)). Finally, the compressor system 100 comprises a controlling means 11 which at the input end receives signals from the pressure control means DW1 and DW2 and at the output end cooperates with the driving means 12. Compressed air, for example, can be taken from the air reservoir 10 by means of a mechanically operated valve 14 as required (e.g. for starting a marine diesel engine).

A particularly suitable and proven embodiment for the control circuit according to Fig. 1 is shown in Fig. 2. The circuit has been designed for a driving means which comprises a three-phase asynchronous motor 15 including a pole-changing (in particular between 4 and 6 poles). The circuit is connected to a three-phase mains supply 16 by means of a main switch Q1. Said three-phase asynchronous motor 15 with its 6-terminal switching means can be connected to the mains supply by means of a motor starting contactor K6M and a motor protection plate F6M while with its 4-terminal switching means it can be connected to the mains supply by means of a motor starting contactor K4M and a motor protection plate F4M.

Furthermore, a control voltage for the windings of the motor starting contactors K6M and K4M is extracted from the mains supply by means of a control voltage transformer TR11. The control voltage can be supplied in different ways by means of a control selector switch S1 which can be set at the positions „Manual operation" (H), „Off" (0) and „Automatic" (A).

In the position „Manual operation" the control voltage is put on the winding of the motor starting contactor K6M by means of a normally closed contact and is put on the winding of the motor starting contactor K4M by means of a second pressure control means DW2. In the position „Automatic" the control voltage is put on the winding of the motor starting

contactor K4M by means of the series connection of the two pressure control means DW1 and DW2. The normally open contact of an auxiliary relay K11 is connected in parallel to the second pressure control means, the winding of which auxiliary relay parallels with the winding of the motor starting contactor K4M.

As soon as the control selector switch S1 is switched to the position „Manual operation" the first pressure control means DW1 is put out of action. Accordingly, the first minimum pressure pmin1 is not controlled. The second pressure control means DW2 is closed as soon as the pressure of the air reservoir 10 falls below pmin2. The motor starting contactor K4M pulls up, whereupon the supply of the control voltage to the motor starting contactor K6M, at the same time, is interrupted by opening the normally closed contact of K4M and the three-phase asynchronous motor 15 is started by closing the normally open contact of K4M in its 4-terminal configuration, i.e. at nominal speed Nnenn. Moreover, during pulling up of the motor starting contactor K4M, the winding of the auxiliary relay K11 is put on the control voltage, too, so that this relay pulls up as well and closes its normally open contact (K11). Both relays provide a self-locking connection which is only interrupted when the control selector switch S1 changes from the position „Manual operation" (H) to the position „Off" (O).

The second pressure control means DW2 is opened as soon as the pressure of the air reservoir 10 is above

pmin2. The control voltage is put on the winding of the motor starting contactor K6M by means of the (closed) normally closed contact of the motor starting contactor K4M; and the contactor pulls up and starts the three-phase asynchronous motor 15 in its 6-terminal configuration, i.e. at reduced speed Nred. Also in this case, the driving means is only turned off when the control selector switch S1 is switched to the position „Off".

The control voltage is put on the winding of the motor starting contactor K4M by means of the series connection of DW1 and DW2 while it is put on the winding of the motor starting contactor K6M by means of DW1 and the normally closed contact of K4M as soon as the control selector switch S1 is switched to the position „Automatic" (A). The first pressure control means DW1 turns on as soon as the pressure of the air reservoir 10 falls below the first minimum pressure pmin1. As the second pressure control means DW2 is opened, only the motor starting contactor K6M pulls up via the closed normally closed contact of K4M and the motor 15 starts at reduced speed Nred. In case the withdrawal of air from the air reservoir 10 is such low that the compressor 13 increases the pressure to pmax again at reduced speed, the first pressure control means DW1 opens and the refilling procedure has come to an end.

If, however, the withdrawal of air is such high that in spite of the compressor 13 starting at reduced speed the pressure continues dropping and falls below

the second minimum pressure pmin2, the second pressure control means DW2 closes as well. The motor starting contactor K4M pulls up and by opening its normally closed contact (K4M) causes the motor starting contactor K6M to drop out. At the same time, the auxiliary relay K11 pulls up as well and provides a self-locking connection together with the motor starting contactor K4M.

The motor 15 then starts at full nominal speed Nnenn and refills the air reservoir until the maximum pressure pmax is exceeded and the first pressure control means DW1 opens. The opening of the second pressure control means DW2 taking place in the meantime as soon as its (lower) maximum pressure is exceeded does not have any influence on the procedure since the second pressure control means DW2 is lockingly by-passed by means of the auxiliary relay K11.

From the system according to Fig. 1 and the circuit according to Fig. 2 the charge- and discharge diagram of pressure p of the air reservoir 10 for the time T results which diagram is shown in Fig. 3. At the beginning of the operation at TO the compressor 13 is operated at nominal speed and, starting from an ambient pressure pu, fills the air reservoir 10 at rated power until the maximum pressure pmax is reached at instant T1. The first pressure control means DW1 opens as soon as this pressure is reached and the controlling means 11 turns off the driving means 12 (operating phase I). If now during the time after T1 the pressure of the air reservoir 10 slowly

drops as a result of taking air therefrom, the first pressure control means DW1 closes if there has not come up to the first minimum pressure pmin1 at T2. The controlling means 11 now turns on the driving means 12 at reduced speed Nred so that the air reservoir 10 is refilled from T2 to T3 again. The driving means turns off again as soon as the maximum pressure pmax is reached at T3.

The sequential refilling is carried through at reduced speed in the way described above until - as shown in Fig. 3 between T3 and T4 - the pressure of the air reservoir 10, as a result of the considerable withdrawal of air, drops substantially faster and the pressure falls below the second minimum pressure pmin2 (at T4) controlled by the second pressure control means DW2. This falling below the second minimum pressure pmin2 signalizes that the refilling at a reduced speed Nred is not sufficient. For this reason, the second pressure control means DW2 turns on the driving means 12 at nominal speed Nnenn so that refilling of the air reservoir 10 - as also done during the starting phase TO to T1 - is carried through with all the compressor power available until the maximum pressure pmax is reached again at T5.

With the construction of this system and this working concept it is achieved that in the normal case of the insignificant withdrawal of air the compressor is operated economically so as to reduce wear while in the special case of the more considerable withdrawal

of air the full power of the compressor is made available.

List of the reference numbers

10	air reservoir
11	controlling means
12	driving means
13	compressor
14	valve
15	three-phase asynchronous motor
16	three-phase mains supply
100	compressor system
DW1, 2	pressure control means
F4M	4-terminal motor protection plate
F6M	6-terminal motor protection plate
K11	auxiliary relay
K4M	4-terminal motor starting contactor
K6M	6-terminal motor starting contactor
Nnenn	nominal speed
Nred	reduced speed
pmax	maximum pressure
pmin1, 2	minimum pressure
Q1	main switch
S1	control selector switch
TO-5	time
TR11	control voltage transformer

Patent Claims

1. A compressor system (100) which comprises a compressor (13) which with its exit is connected to an air reservoir (10) and is driven by a driving means (12) which in a first mode of operation is operated at a nominal speed (Nnenn), as well as a first pressure control means (DW1) which controls the pressure of said air reservoir (10) and turns on said driving means (12) by means of a controlling means (11) as soon as the pressure of said air reservoir (10) falls below a first minimum pressure (pmin1), and turns off said driving means (12) again as soon as a maximum pressure (pmax) in said air reservoir (10) is exceeded,
characterized in
that, besides the first mode of operation in which said driving means (12) is operated at a nominal speed (Nnenn), said driving means (12) in a second mode of operation is operated at at least one further speed (Nred) being reduced with respect to the nominal speed (Nnenn), that said first pressure control means (DW1) only turns on if the pressure falls below the first minimum pressure (pmin1) due to a decrease of pressure, and that in the second mode of operation said first pressure control means (DW1) controls said driving means (12) at a reduced speed (Nred).

2. The compressor system according to claim 1, characterized in
that the pressure of the air reservoir (10) is controlled by a second pressure control means (DW2)

which turns on as soon as the pressure falls below a second minimum pressure (pmin2) as a result of a pressure drop, which second minimum pressure is smaller than the first minimum pressure (pmin1), and that said second pressure control means (DW2) switches said driving means (12) from the second mode of operation to the first mode of operation, in which said driving means (12) is operated at nominal speed (Nnenn).

3. The compressor system according to any of the claims 1 or 2,
characterized in
that said driving means comprises a three-phase asynchronous motor including a frequency control, the number of revolutions of which is continuously variable.

4. The compressor system according to any of the claims 1 or 2,
characterized in
that said driving means comprises a three-phase asynchronous motor (15) including a pole-changing, the number of revolutions of which is continuously variable.

5. The compressor system according to claims 2 and 4,
characterized in
that said three-phase asynchronous motor (15) can be connected to a three-phase mains supply by means of a first motor starting contactor (K6M) with a first number of poles, and by means of a second motor

starting contactor (K4M) with a second number of poles which is smaller than the first number of poles, that said first and said second pressure control means (DW1, DW2) are connected in series and control said second motor starting contactor (K4M), that said first motor starting contactor (K6M) is connected to the connecting point between said first and said second pressure control means (DW1 resp. DW2) by means of a normally closed contact of said second motor starting contactor (K4M), and that said second pressure control means (DW2) can be by-passed by means of the normally open contact of an auxiliary relay (K11), which auxiliary relay (K11) parallels with said second motor starting contactor (K4M).

6. A compressor system substantially as hereinbefore described with reference to and as illustrated in, the accompanying drawings.

The Patent Office

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Application No: GB 9512676.9
Claims searched: 1-5

Examiner: Mr Andrew Bartlett
Date of search: 2 August 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): G3R (RBF,RBU,RAD & RAF)

Int Cl (Ed.6): F01B 25/00 & 02; F04B 49/06,08 & 20; G05D 16/02, 18 & 20;

Other: ONLINE:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage			Relevant to claims
A	US 4686439	(Cunningham et al)	See col 1 lines 39-46 in particular.	1 at least
A	US 4492526	(Hartwig et al)	See whole document.	1 at least.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.